US008590314B2

(12) **United States Patent**
McMahan et al.

(10) **Patent No.: US 8,590,314 B2**
(45) **Date of Patent: Nov. 26, 2013**

(54) COMBUSTOR LINER HELICAL COOLING APPARATUS

(75) Inventors: **Kevin Weston McMahan**, Greer, SC (US); **Ronald James Chila**, Greer, SC (US)

(73) Assignee: **General Electric Company**, Schenectady, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 809 days.

(21) Appl. No.: **12/757,610**

(22) Filed: **Apr. 9, 2010**

(65) **Prior Publication Data**

US 2011/0247341 A1   Oct. 13, 2011

(51) **Int. Cl.**
F02C 1/00 (2006.01)
F02G 3/00 (2006.01)

(52) **U.S. Cl.**
USPC **60/752**; 60/753; 60/754; 60/755; 60/756; 60/757; 60/758; 60/759; 60/760

(58) **Field of Classification Search**
USPC 60/752–760
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,543,781	A *	10/1985	Rice	60/804
5,724,816	A *	3/1998	Ritter et al.	60/752
5,737,922	A *	4/1998	Schoenman et al.	60/752
6,282,905	B1 *	9/2001	Sato et al.	60/752
7,010,921	B2 *	3/2006	Intile et al.	60/752
8,307,654	B1 *	11/2012	Liang	60/752
2004/0050059	A1	3/2004	Bunker	
2004/0079082	A1	4/2004	Bunker	
2005/0044857	A1	3/2005	Glezer et al.	
2010/0005803	A1	1/2010	Tu et al.	

FOREIGN PATENT DOCUMENTS

JP	2002155758 A *	5/2002		F02C 7/18

OTHER PUBLICATIONS

Search Report and Opinion issued Oct. 26. 2011 in corresponding EP Application No. 11161628.0.

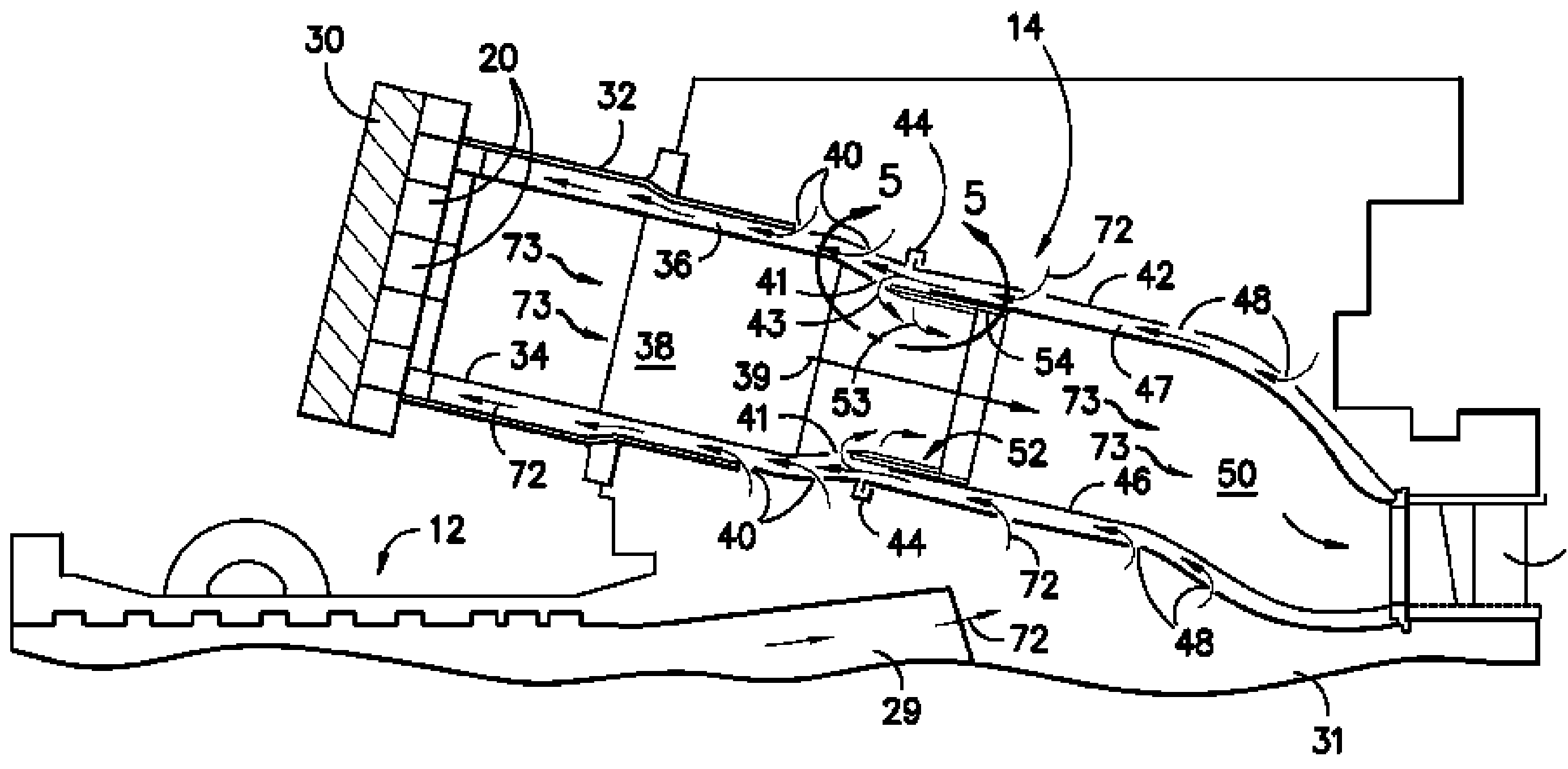
* cited by examiner

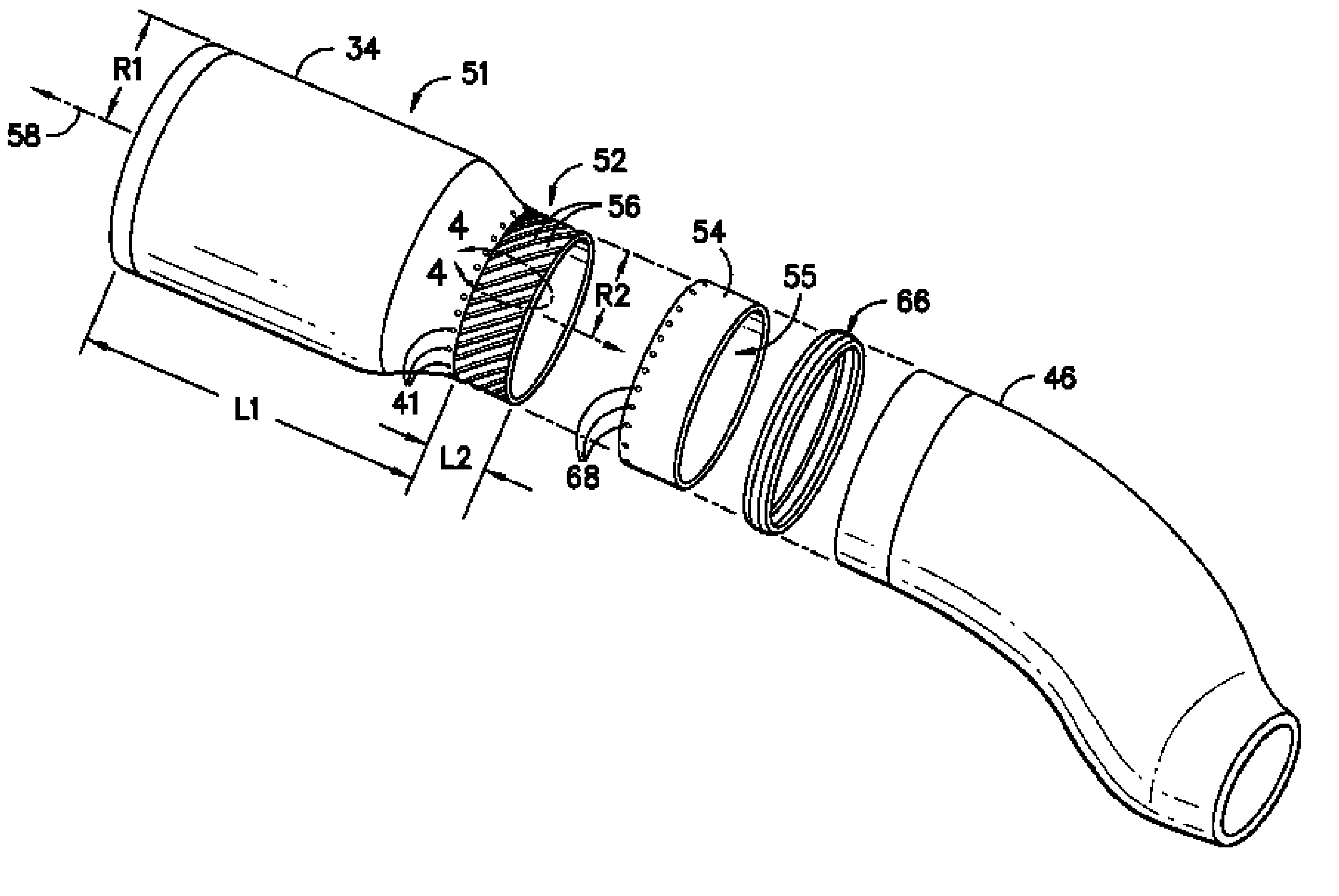
Primary Examiner — Gerald L Sung
Assistant Examiner — Craig Kim
(74) *Attorney, Agent, or Firm* — Dority & Manning, PA

(57) ABSTRACT

A combustor liner is provided. The combustor liner may include an upstream portion and a downstream end portion. The upstream portion may have a radius and a length along a generally longitudinal axis. The downstream end portion may have a radius and a length along the generally longitudinal axis. The downstream end portion may define a plurality of channels. Each of the plurality of channels may extend helically through the length of the downstream end portion. Each of the plurality of channels may be configured to flow an air flow therethrough, cooling the downstream end portion.

20 Claims, 7 Drawing Sheets





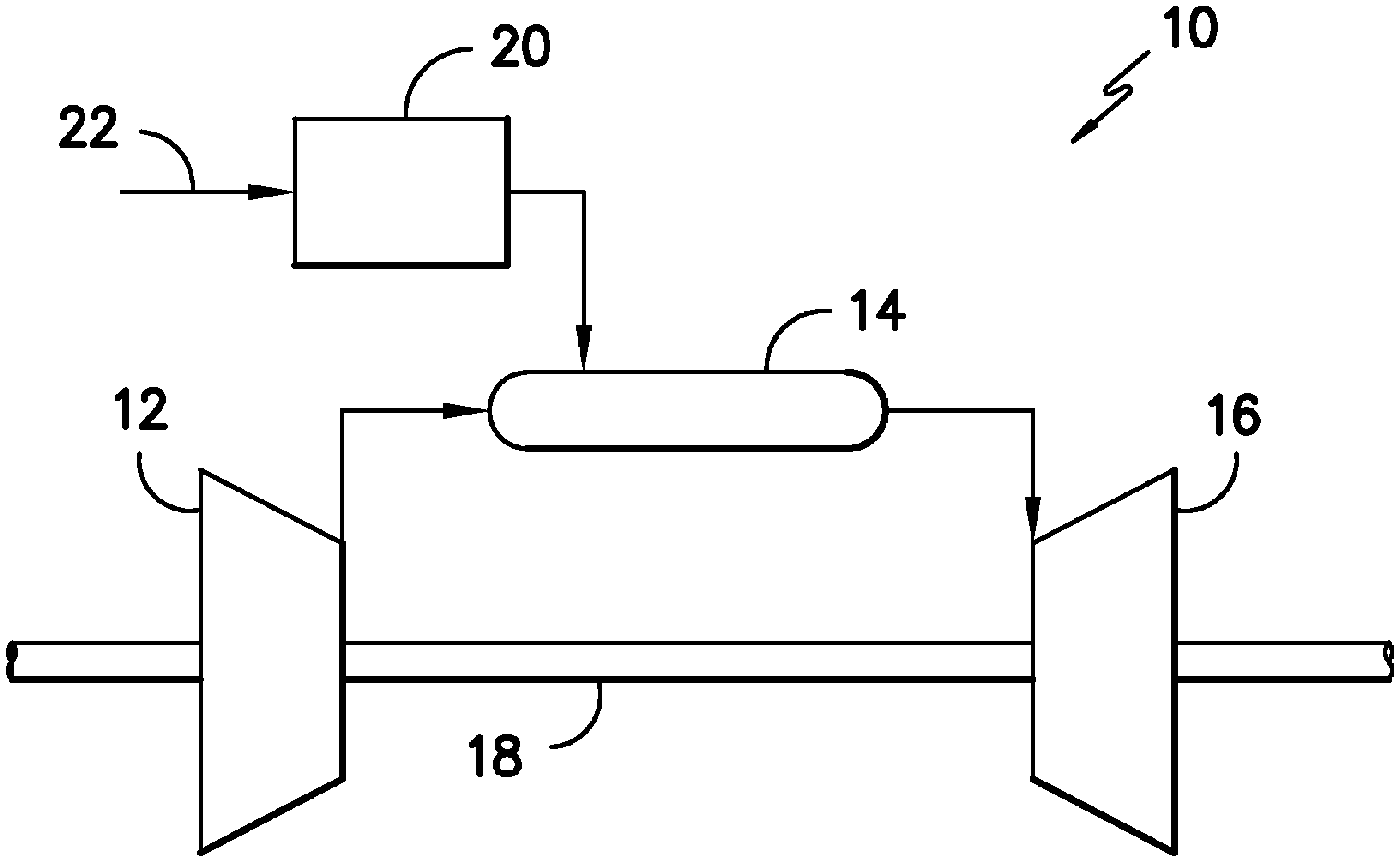


FIG. –1–

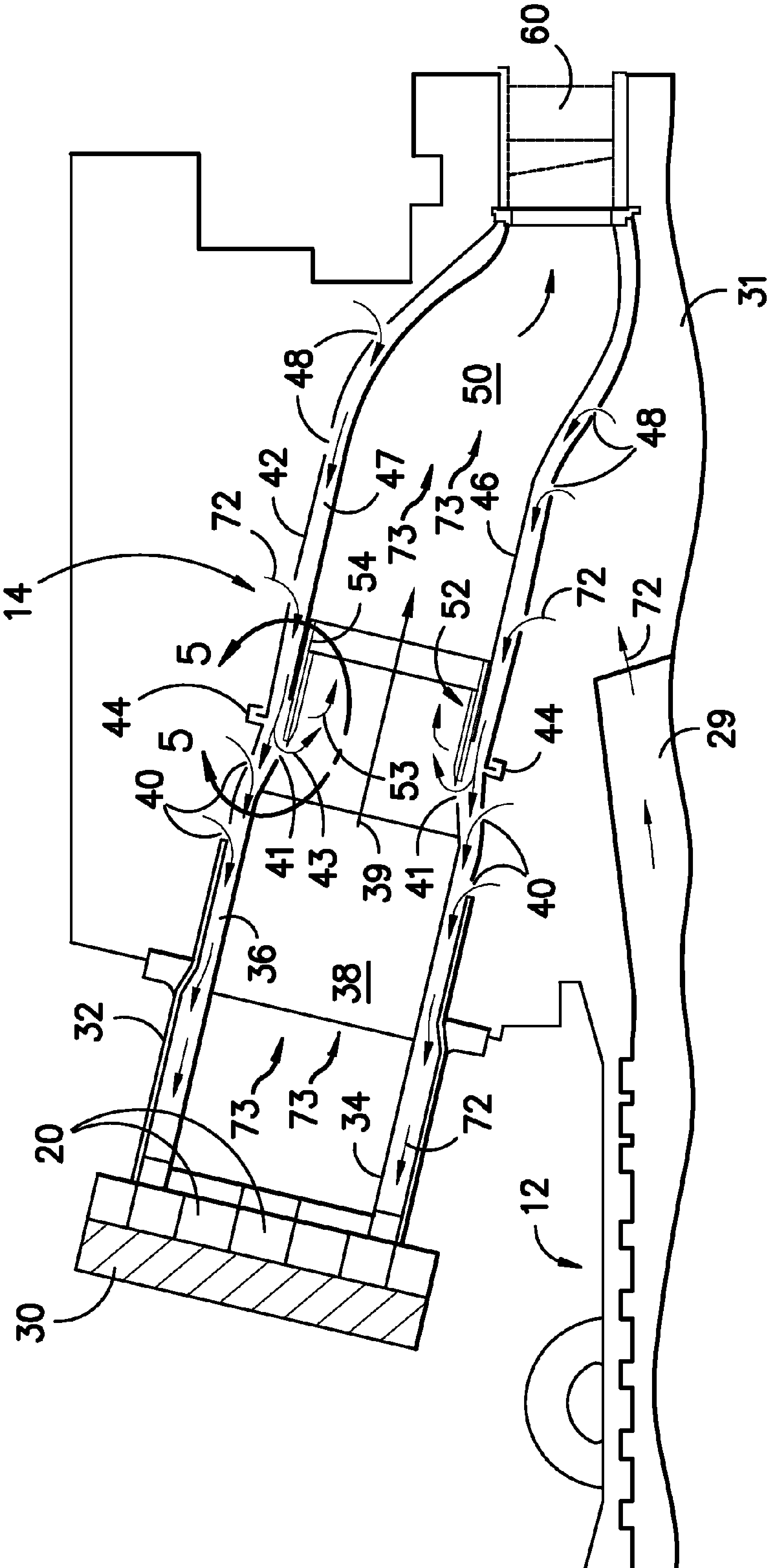

60
31
48
50
48
42
47
72
73
73
73
46
14
54
52
72
72
5
44
44
5
53
29
40
41
43
39
41
40
36
38
32
73
73
34
72
20
12
30

FIG. –2–

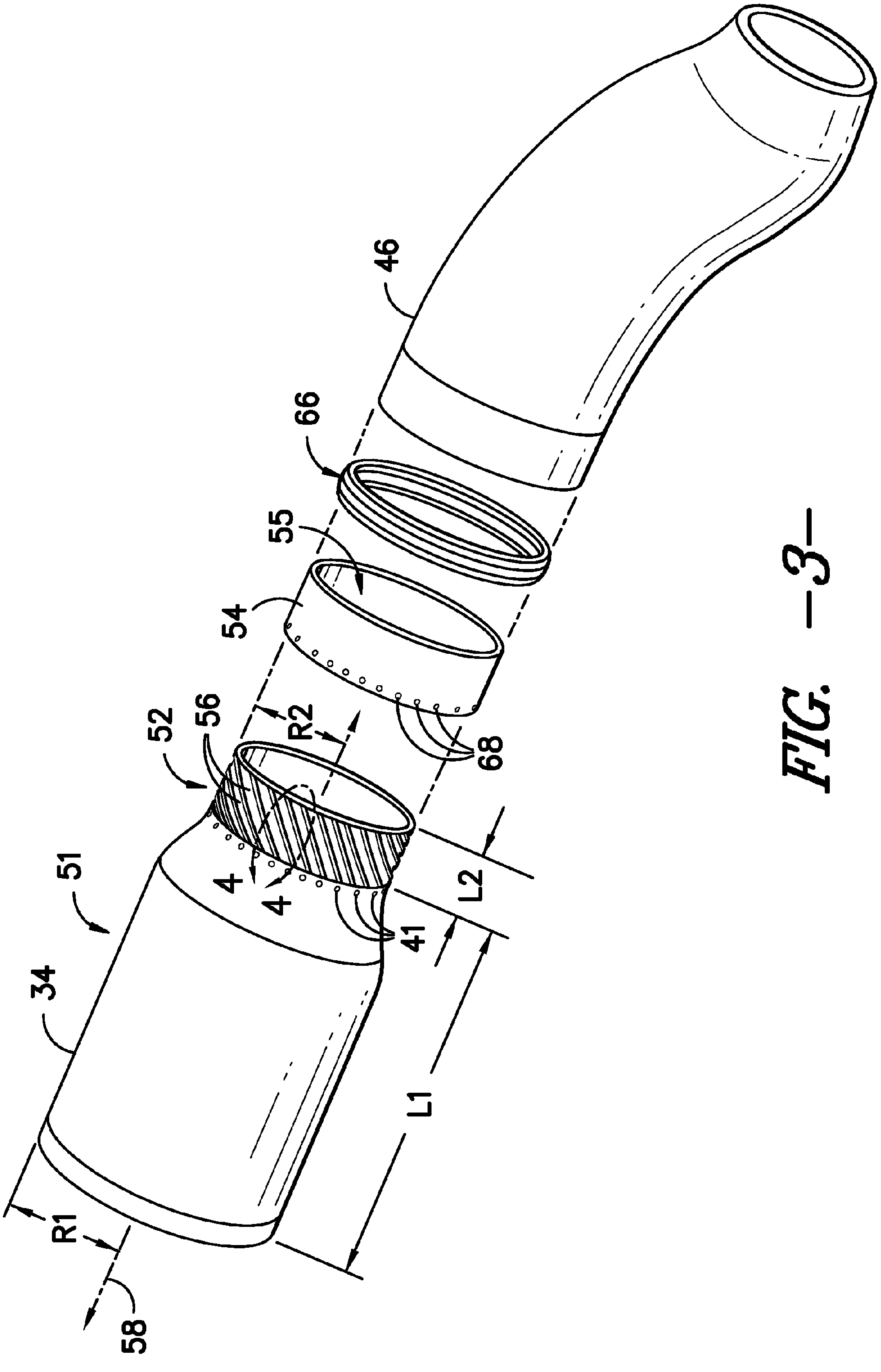


FIG. —3—

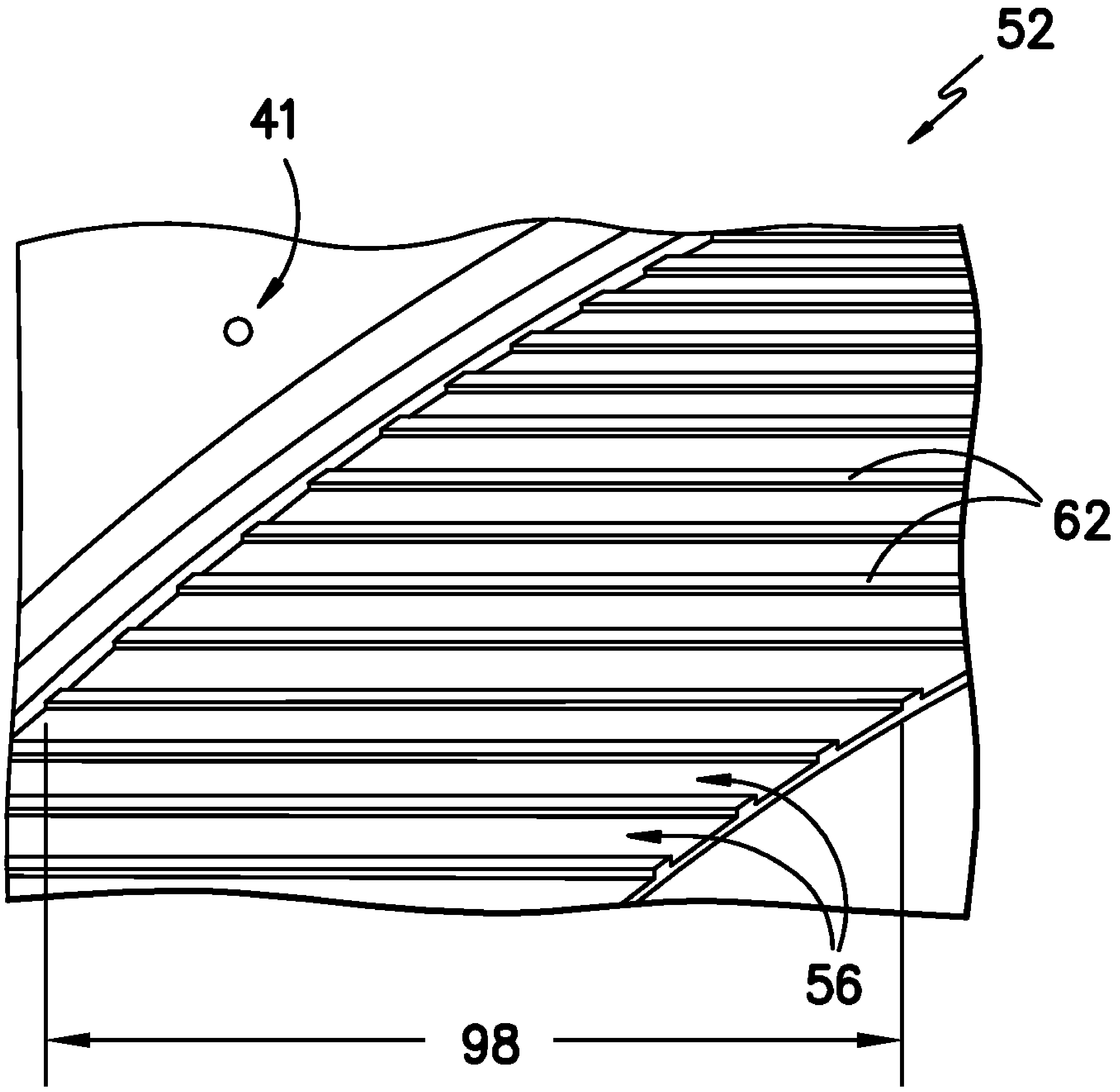


FIG. –4–

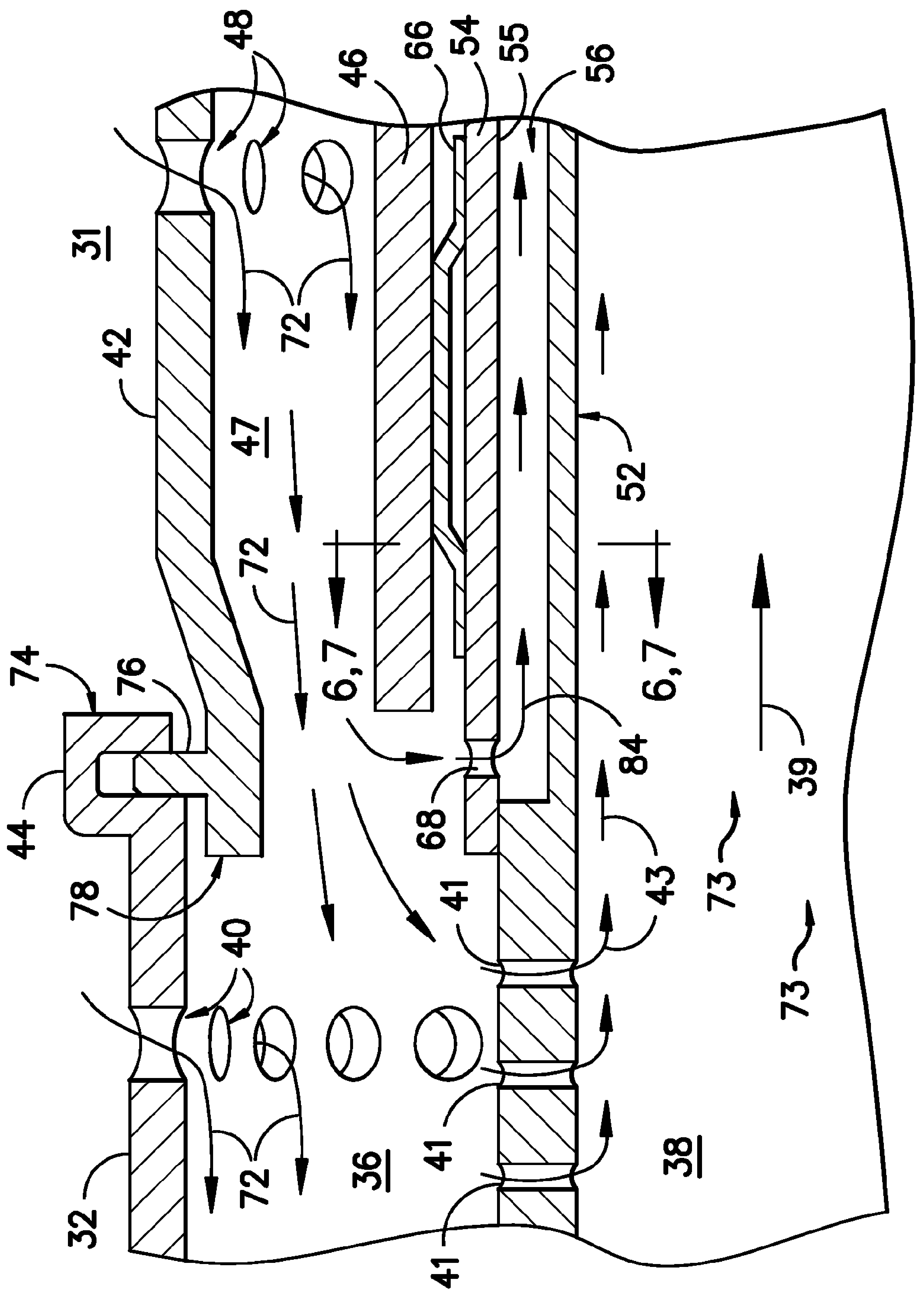

48
46
66
54
55
56
31
42
72
47
52
72
6,7
6,7
74
76
44
78
40
72
36
32
68
84
41
41
41
41
43
73
73
39
38

FIG. –5–

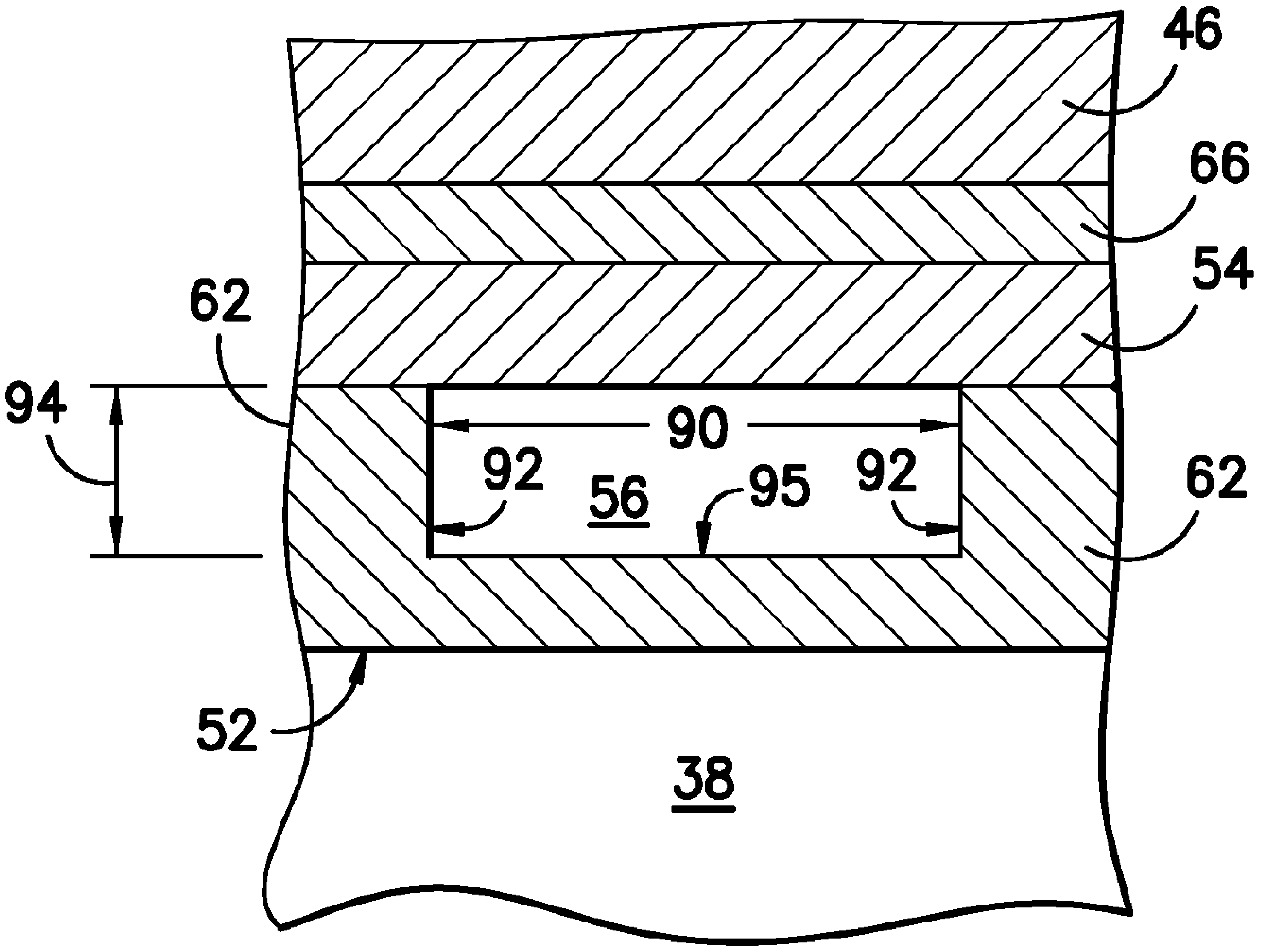

46
66
54
62
94
90
92
56
95
92
62
52
38

FIG. –6–

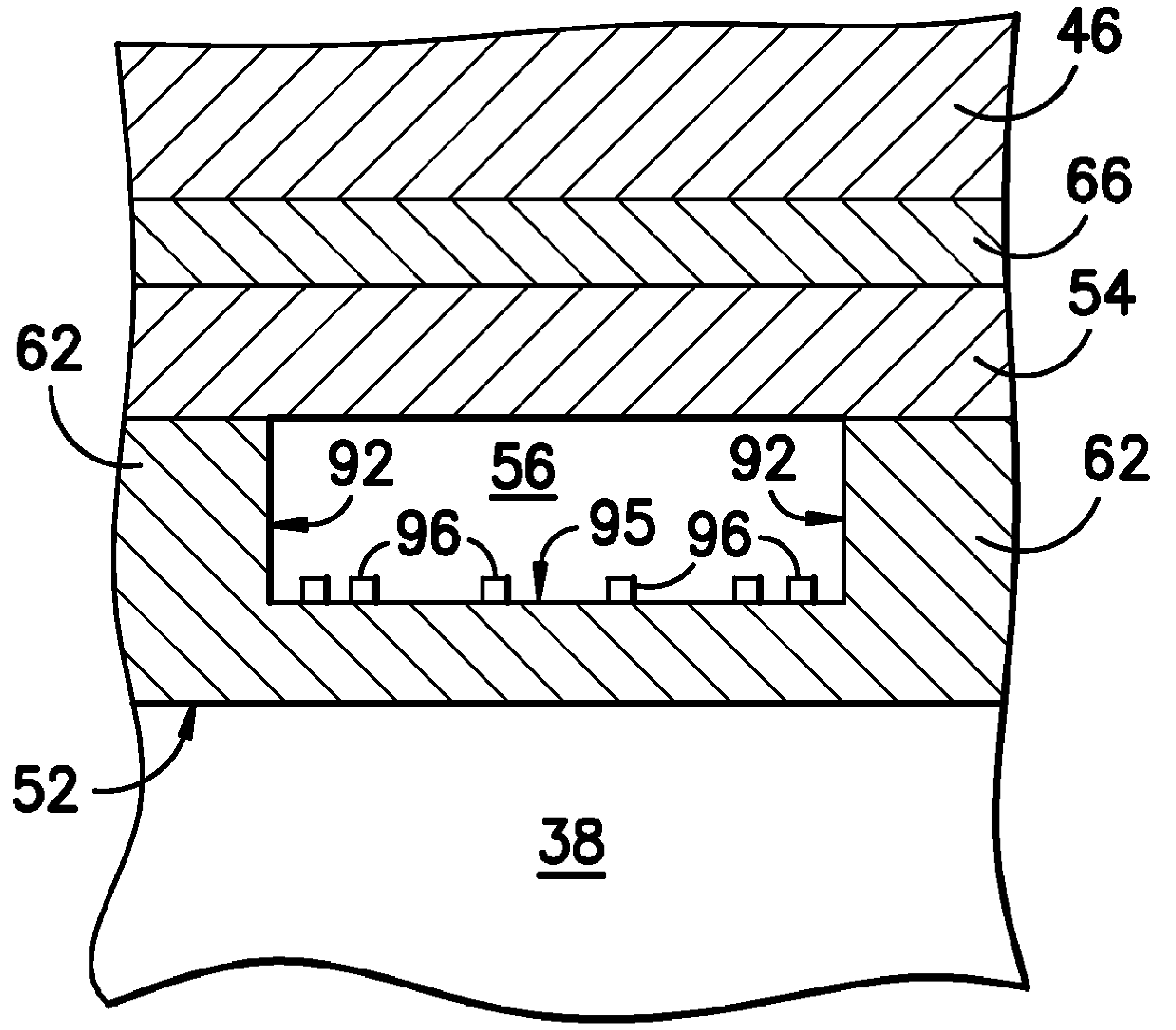

46
66
54
62
92
56
92
62
96
95
96
52
38

FIG. –7–

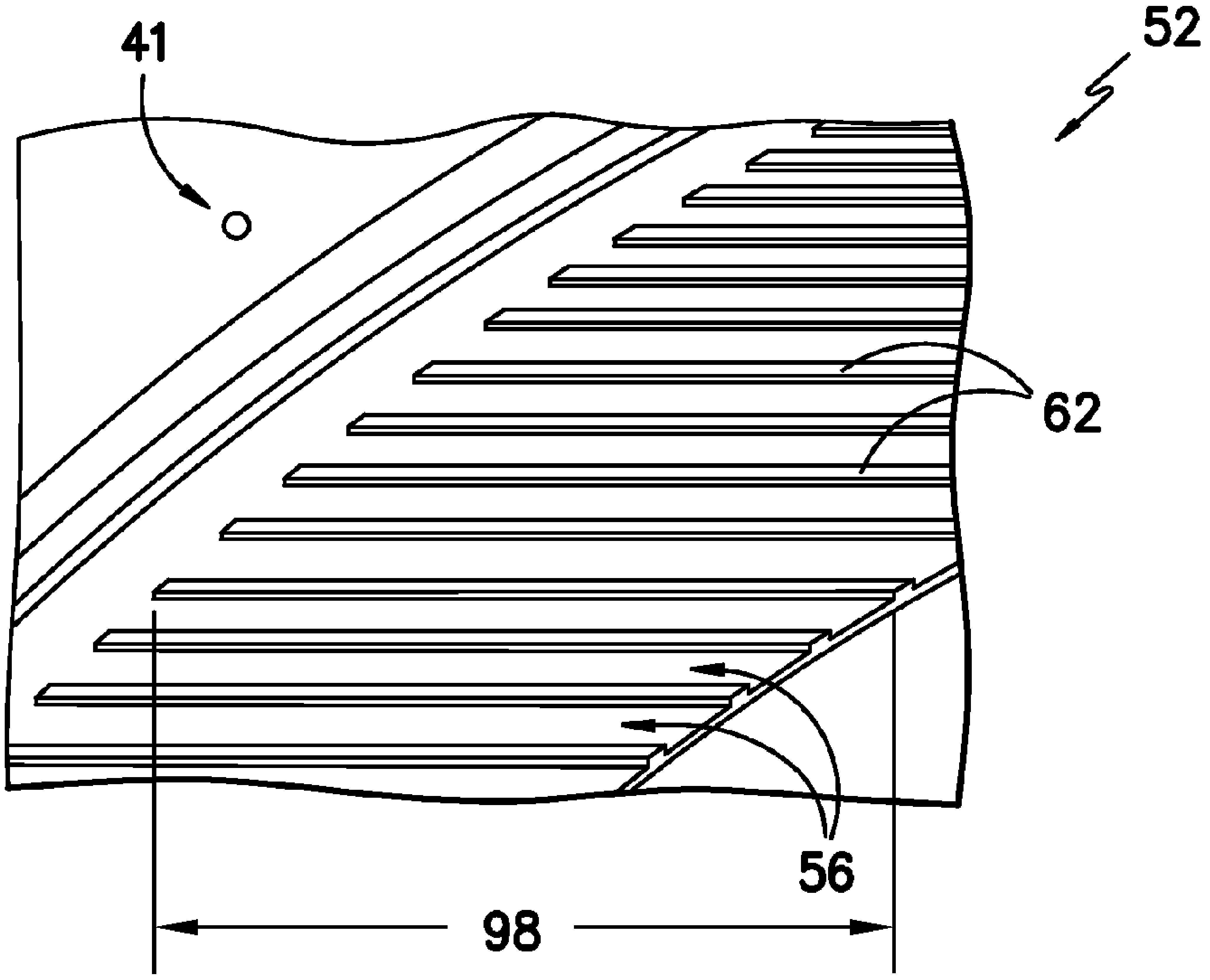


FIG. –8–

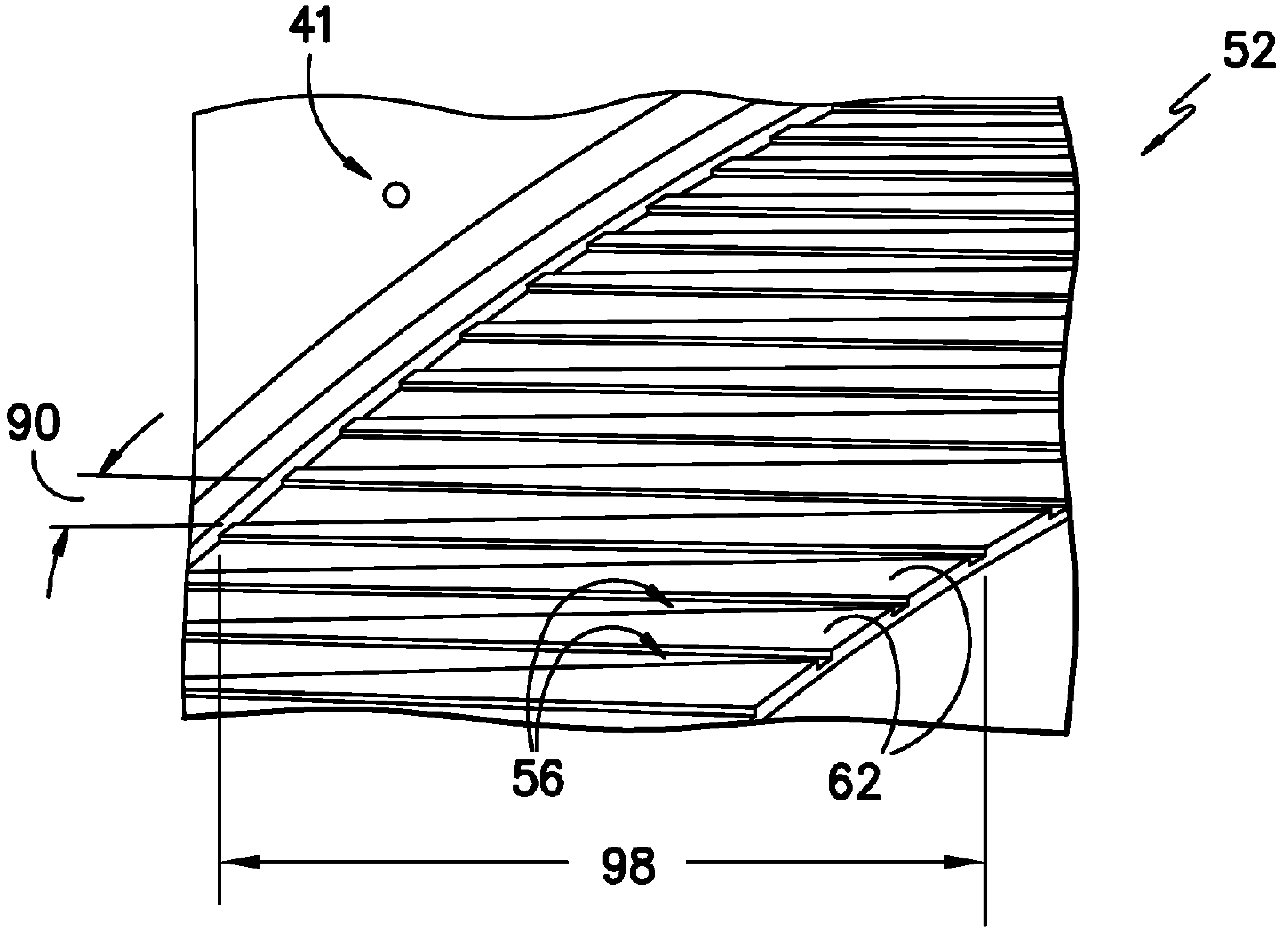


FIG. –9–

COMBUSTOR LINER HELICAL COOLING APPARATUS

FIELD OF THE INVENTION

The subject matter disclosed herein relates generally to gas turbine systems, and more particularly to apparatus for cooling a combustor liner in a combustor of a gas turbine system.

BACKGROUND OF THE INVENTION

Gas turbine systems are widely utilized in fields such as power generation. A conventional gas turbine system includes a compressor, a combustor, and a turbine. During operation of the gas turbine system, various components in the system are subjected to high temperature flows, which can cause the components to fail. Since higher temperature flows generally result in increased performance, efficiency, and power output of the gas turbine system, the components that are subjected to high temperature flows must be cooled to allow the gas turbine system to operate at increased temperatures.

One gas turbine system component that should be cooled is the combustor liner. As high temperature flows, caused by combustion of an air-fuel mix within the combustor, are directed through the combustor, the high temperature flows heat the combustor liner, which could cause the combustor liner to fail. Specifically, the downstream end portion of the combustor liner, which in many combustors has a smaller radius than the combustor liner in general, may be a life-limiting section of the combustor liner which may fail due to exposure to high temperature flows. Thus, in order to increase the life of the combustor liner, the downstream end portion must be cooled.

Various strategies are known in the art for cooling the combustor liner. For example, a portion of the air flow provided from the compressor through fuel nozzles into the combustor may be siphoned to linear, axial channels defined in the downstream end portion of the combustor liner. As the air flow is directed through the axial channels in the direction of flow of the hot gas, the air flow may cool the downstream end portion. However, cooling of the downstream end portion by the air flow within the axial channels is generally limited by the length of the downstream end portion of the combustor liner, which defines the length of the axial channels. Thus, the axial channels may limit the effectiveness of the air flow in cooling the downstream end portion.

Thus, a combustor liner cooling apparatus is desired in the art. For example, an apparatus to cool the downstream end portion of the combustor liner may be advantageous. Further, a downstream end portion of a combustor liner with cooling channels that exceed that length of the downstream end portion, increasing the cooling of the downstream end portion, may be advantageous.

BRIEF DESCRIPTION OF THE INVENTION

Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

In one embodiment, a combustor liner is provided. The combustor liner may include an upstream portion and a downstream end portion. The upstream portion may have a radius and a length along a generally longitudinal axis. The downstream end portion may have a radius and a length along the generally longitudinal axis. The downstream end portion may define a plurality of channels. Each of the plurality of channels may extend helically through the length of the downstream end portion. Each of the plurality of channels may be configured to flow an air flow therethrough, cooling the downstream end portion.

These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWING

A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

FIG. **1** is a schematic illustration of a gas turbine system;

FIG. **2** is a side cutaway view of one embodiment of various components of the gas turbine system of the present disclosure;

FIG. **3** is an exploded perspective view of one embodiment of various components of the combustor of the present disclosure;

FIG. **4** is a partial perspective view of one embodiment of the combustor liner of the present disclosure within line **4-4** of FIG. **3**;

FIG. **5** is a partial cross-sectional view of one embodiment of various components of the combustor of the present disclosure within line **5-5** of FIG. **2**;

FIG. **6** is a partial cross-sectional view of one embodiment of the channels of the present disclosure taken along line **6-6** of FIG. **5**;

FIG. **7** is a partial cross-sectional view of another embodiment of the channels of the present disclosure taken along line **7-7** of FIG. **5**;

FIG. **8** is a partial perspective view of another embodiment of the combustor liner of the present disclosure; and

FIG. **9** is a partial perspective view of yet another embodiment of the combustor liner of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

FIG. **1** is a schematic diagram of a gas turbine system **10**. The system **10** may include a compressor **12**, a combustor **14**, a turbine **16**, and a fuel nozzle **20**. Further, the system **10** may include a plurality of compressors **12**, combustors **14**, turbines **16**, and fuel nozzles **20**. The compressor **12** and turbine **16** may be coupled by a shaft **18**. The shaft **18** may be a single shaft or a plurality of shaft segments coupled together to form shaft **18**.

The gas turbine system **10** may use liquid or gas fuel, such as natural gas or a hydrogen rich synthetic gas, to run the system **10**. For example, the fuel nozzles **20** may intake a fuel supply **22** and an air flow **72** (see FIG. **2**) from a discharge plenum **31** of the compressor **12**, mix the fuel supply **22** with the air flow **72** to create an air-fuel mix, and discharge the air-fuel mix into the combustor **14**. The air-fuel mix accepted by the combustor **14** may combust in a combustion chamber **38** within combustor **14**, thereby creating a hot pressurized exhaust gas, or hot gas flow **73**. The combustor **14** may direct the hot gas flow **73** through a hot gas path **39** within the combustor **14** into the turbine **16**. As the hot gas flow **73** passes through the turbine **16**, the turbine **16** may cause the shaft **18** to rotate. The shaft **18** may be connected to various components of the turbine system **10**, including the compressor **12**. Thus, rotation of the shaft **18** may cause the compressor **12** to operate, thereby compressing the air flow **72**.

Thus, in operation, air flow **72** may enter the turbine system **10** and be pressurized in the compressor **12**. The air flow **72** may then be mixed with fuel supply **22** for combustion within combustor **14**. For example, the fuel nozzles **20** may inject a fuel-air mixture into the combustor **14** in a suitable ratio for optimal combustion, emissions, fuel consumption, and power output. The combustion may generate hot gas flow **73**, which may be provided through the combustor **14** to the turbine **16**.

As illustrated in FIG. **2**, the combustor **14** is generally fluidly coupled to the compressor **12** and the turbine **16**. The compressor **12** may include a diffuser **29** and a discharge plenum **31** that are coupled to each other in fluid communication, so as to facilitate the channeling of air to the combustor **14**. For example, after being compressed in the compressor **12**, air flow **72** may flow through the diffuser **29** and be provided to the discharge plenum **31**. The air flow **72** may then flow from the discharge plenum **31** through the fuel nozzles **20** to the combustor **14**.

The combustor **14** may include a cover plate **30** at the upstream end of the combustor **14**. The cover plate **30** may at least partially support the fuel nozzles **20** and provide a path through which air flow **72** and fuel supply **22** may be directed to the fuel nozzles **20**.

The combustor **14** may comprise a hollow annular wall configured to facilitate air flow **72**. For example, the combustor **14** may include a combustor liner **34** disposed within a flow sleeve **32**. The arrangement of the combustor liner **34** and the flow sleeve **32**, as shown in FIG. **2**, is generally concentric and may define an annular passage or air flow path **36** therebetween. In certain embodiments, the flow sleeve **32** and the combustor liner **34** may define a first or upstream hollow annular wall of the combustor **14**. The flow sleeve **32** may include a plurality of inlets **40**, which provide a flow path for at least a portion of the air flow **72** from the compressor **12** through the discharge plenum **31** into the annular passage or air flow path **36**. In other words, the flow sleeve **32** may be perforated with a pattern of openings to define a perforated annular wall. The interior of the combustor liner **34** may define a substantially cylindrical or annular combustion chamber **38** and at least partially define a hot gas path **39** through which hot gas flow **73** may be directed.

Downstream from the combustor liner **34** and the flow sleeve **32**, an impingement sleeve **42** may be coupled to the flow sleeve **32**. The flow sleeve **32** may include a mounting flange **44** configured to receive a portion of the impingement sleeve **42**. A transition piece **46** may be disposed within the impingement sleeve **42**, such that the impingement sleeve **42** surrounds the transition piece **46**. A concentric arrangement of the impingement sleeve **42** and the transition piece **46** may define an annular passage or air flow path **47** therebetween. The impingement sleeve **42** may include a plurality of inlets **48**, which may provide a flow path for at least a portion of the air flow **72** from the compressor **12** through the discharge plenum **31** into the air flow path **47**. In other words, the impingement sleeve **42** may be perforated with a pattern of openings to define a perforated annular wall. An interior cavity **50** of the transition piece **46** may further define hot gas path **39** through which hot gas flow **73** from the combustion chamber **38** may be directed into the turbine **16**.

As shown, the air flow path **47** is fluidly coupled to the air flow path **36**. Thus, together, the air flow paths **47** and **36** define an air flow path configured to provide air flow **72** from the compressor **12** and the discharge plenum **31** to the fuel nozzles **20**, while also cooling the combustor **14**.

The transition piece **46** may be coupled to combustor liner **34** generally about a downstream end portion **52**. An annular wrapper **54** and a sealing ring **66** may be disposed between the downstream end portion **52** and the transition piece **46**. The sealing ring **66** may provide a seal between the combustor liner **34** and the transition piece **46**. For example, the sealing ring **66** may seal the outer surface of the annular wrapper **54** to the inner surface of the transition piece **46**.

As discussed above, the turbine system **10**, in operation, may intake an air flow **72** and provide the air flow **72** to the compressor **12**. The compressor **12**, which is driven by the shaft **18**, may rotate and compress the air flow **72**. The compressed air flow **72** may then be discharged into the diffuser **29**. The majority of the compressed air flow **72** may then be discharged from the compressor **12**, by way of the diffuser **29**, through the discharge plenum **31** and into the combustor **14**. Additionally, a small portion (not shown) of the compressed air flow **72** may be channeled downstream for cooling of other components of the turbine engine **10**.

A portion of the compressed air within the discharge plenum **31** may enter the air flow path **47** by way of the inlets **48**. The air flow **72** in the air flow path **47** may then be channeled upstream through air flow path **36**, such that the air flow is directed over the downstream end portion **52** of the combustor liner **34**. Thus, an air flow path is defined in the upstream direction by air flow path **47** (farmed by impingement sleeve **42** and transition piece **46**) and air flow path **36** (formed by flow sleeve **32** and combustor liner **34**).

A portion of the air flow **72** flowing in the upstream direction may be directed from air flow path **47** though the annular wrapper **54** to the downstream end portion **52** of the combustor liner **34**. For example, a plurality of inlet passages **68** (see FIGS. **3** and **5**) defined by the annular wrapper **54** may provide a flow path through the annular wrapper **54** to the downstream end portion **52**.

The air flow **72** that is not directed through the annular wrapper **54** may continues to flow upstream through air flow path **36** toward the cover plate **30** and fuel nozzles **20**. Accordingly, air flow path **36** may receive air flow **72** from both air flow path **47** and inlets **40**. As shown in FIG. **2**, a portion **43** of the air flow **72** within the air flow path **36** may be directed into one or more bypass openings **41** on the combustor liner **34**. The bypass openings **41** may extend radially through the combustor liner **34** and provide a direct flow path into the combustion chamber **38** that bypasses the channels **56** defined in the downstream end portion **52**. The air flow **43** that flows into the combustion chamber **38** through the bypass openings **41** may provide a cooling film along the inner surface of the combustor liner **34**. The remaining air flow **72** through the air flow path **36** may then be channeled upstream towards the fuel nozzles **20**, wherein the air flow **72** may be mixed with fuel supply **22** and ignited within the combustion chamber **38** to create hot gas flow **73**. The hot gas flow **73** may be channeled through the combustion chamber **38** along the hot gas path **39** into the transition piece cavity **50** and through a turbine nozzle **60** to the turbine **16**.

FIG. **3** illustrates an exploded perspective view of one embodiment of various components of the combustor **14** of the present disclosure. Particularly, FIG. **3** is intended to provide a better understanding of the relationship between the combustor liner **34**, the annular wrapper **54**, and the transition piece **46**. As shown, the combustor liner **34** may include an upstream portion **51** and a downstream end portion **52**. The upstream portion **51** may have an axial length L**1** when measured along a longitudinal axis **58**. The downstream end portion **52** may have an axial length L**2** when measured along the longitudinal axis **58**. In the illustrated embodiment, a radius R**1** of the upstream portion **51** of the combustor liner **34** may be greater than a radius R**2** of the downstream end portion **52** of the combustor liner **34**. In other embodiments, however, the radii R**1** and R**2** may be equal, or the radius R**2** may be greater than the radius R**1**. Further, it should be understood that the radii R**1** and R**2** may taper throughout the lengths L**1** and L**2**, or throughout a portion of the lengths L**1** and L**2**, of the upstream portion **51** and downstream end portion **52**, respectively. For example, the radii R**1** and R**2** may be reduced throughout the lengths L**1** and L**2**, or throughout a portion of the lengths L**1** and L**2**, in the direction of hot gas flow **73** or air flow **84**, which will be discussed in detail below. Alternately, the radii R**1** and R**2** may be enlarged throughout the lengths L**1** and L**2**, or throughout a portion of the lengths L**1** and L**2**, in the direction of hot gas flow **73** or air flow **84**. Further, radius R**1** may be tapered while R**2** remains constant, or R**2** may be tapered while R**1** remains constant.

The length L**2** of the downstream end portion **52** of the combustor liner **34** may generally be less than the length L**1** of the upstream portion **51** of the combustor liner **34**. Further, in one embodiment, the length L**2** of the downstream end portion **52** may be approximately 10-20 percent of the total length (L**1**+L**2**) of the combustor liner **34**. However, it should be appreciated that in other embodiments, the length L**2** could be greater than 20 percent or less than 10 percent of the total length of the combustor liner **34**. For example, in other embodiments, the longitudinal length L**2** of the downstream end portion **52** may be at least less than approximately 5, 10, 15, 20, 25, 30, or 35 percent of the total length of the combustor liner **34**.

The annular wrapper **54** may be configured to mate with the combustor liner **34** generally about the downstream end portion **52** in a telescoping, coaxial, or concentric overlapping relationship. The transition piece **46** may be coupled to the combustor liner **34** generally about the downstream end portion **52** and the annular wrapper **54**. The sealing ring **66** may be disposed between the annular wrapper **54** and the transition piece **46** to facilitate the coupling. For example, the sealing ring **66** may provide a seal between the combustor liner **34** and the transition piece **46**. As shown, the annular wrapper **54** may define a plurality of inlets passages **68** generally near the upstream end of the annular wrapper **54**. In the illustrated embodiment, the inlet passages **68** are depicted as a plurality of openings disposed circumferentially (relative to the axis **58**) about the upstream end of the annular wrapper **54** and extending radially therethrough. However, it should be understood that the inlet passages **68** may be defined in any arrangements and at any locations on the annular wrapper **54**. The openings defined by the inlet passages **68** may include holes, slots, or a combination of holes and slots, for example. Further, the openings defined by the inlet passages **68** may be any openings or passages known in the art. Further, the inlet passages **68** may have diameters of approximately 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, or 0.10 inches or, in other embodiments, less than 0.01 inches or greater than 0.10 inches.

The inlet passages **68** may be configured to provide a portion **84** (see FIG. **5**) of the air flow **72** to the downstream end portion **52** of the combustor liner **34**. Further, an inner surface **55** of the annular wrapper **54** and channels **56** defined in the downstream end portion **52** may form passages to receive the air flow **84** provided via the inlets **68**. For example, in one embodiment, each inlet **68** may supply an air flow **84** by diverting a portion of the air flow **72** flowing upstream towards the fuel nozzles **20** through air flow paths **36** and **47** to a respective channel **56** defined in the downstream end portion **52**. As the air flow **84**, which is generally substantially cooler relative to the temperature of the hot gas flow **73** in the hot gas path **39** within the combustion chamber **38**, flows into and through the channels **56**, heat may be transferred away from the downstream end portion **52** of the combustor liner **34**, thus cooling the downstream end portion **52** and the combustor liner **34**. The combustor liner **34** may also includes bypass openings **41** which, as discussed above, may provide a cooling film along the inner surface of the combustor liner **34**, thus providing additional insulation for the combustor liner **34**.

FIG. **4** is a partial perspective view of the downstream end portion **52** of the combustor liner **34** within the circular region defined by the arcuate line **4-4** of FIG. **3**. The downstream end portion **52** of the combustor liner **34** may define a plurality of channels **56**. The plurality of channels **56** may be arranged circumferentially about the downstream end portion **52** of the combustor liner **34**. In an exemplary aspect of an embodiment, the plurality of channels **56** may extend helically through the length L**2** of the downstream end portion **52**. For example, the plurality of channels **56** may extend helically through approximately the entire length L**2** of the downstream end portion. Alternatively, however, the channels **56** may extend helically through only a portion of the length L**2** of the downstream end portion **52**, as shown in FIG. **8**. Further, it should be understood that various of the channels **56** may extend helically through approximately the entire length L**2**, while other channels **56** may extend through only a portion of the length L**2**.

Each of the plurality of channels **56** may be configured to flow an air flow **84** therethrough, cooling the downstream end portion **52**. For example, the channels **56** may define flow paths generally parallel to one another, the flow paths extending helically with respect to the length L**2** and the longitudinal axis **58** of the combustor liner **34**. In one embodiment, the channels **56** may be formed by removing a portion of the outer surface of the downstream end portion **52**, such that each channel **56** is a recessed groove between adjacent raised dividing members **62**. Thus, the channels **56** may be defined by alternating helical grooves and helical dividing members **62** about a circumference of the downstream end portion **52**. As will be appreciated, the channels **56** may be formed using any suitable technique, such as milling, casting, molding, or laser etching/cutting, for example.

In an exemplary aspect of an embodiment, each of the plurality of channels **56** may have a length **98** that is greater than the axial length L**2** of the downstream end portion **52**. For example, the channels **56** may have lengths **98** of approximately 4, 8, 12, or 16 inches. In other embodiments, however, the channels **56** may have lengths **98** that are greater than 16 inches or less than 4 inches. The axial length L**2** of the downstream end portion **52**, however, may be approximately 3, 6, 9, or 12 inches. In other embodiments, however, the axial length L**2** may be greater than 12 inches or less than 3 inches.

Alternatively, however, each of the plurality of channels **56** may have a length **98** that is substantially equal to, or less than, the axial length L**2** of the downstream end portion **52**. Further, it should be understood that various of the channels may have a length **98** that is greater than the axial length L**2** while others have a length **98** that is substantially equal to, or less than, the axial length.

As shown in FIG. **6**, each of the plurality of channels **56** may have a width **90**. In one embodiment, for example, the channels **56** may each have a width **90** of approximately 0.25 inches, 0.5 inches, 0.75 inches, or 1 inch. In other embodiments, the width **90** may be less than 0.25 inches or greater than 1 inch. Further, in one embodiment, the width **90** of each of the channels **56** may be substantially constant throughout the length **98** of the channel. However, in another embodiment, the width **90** of each of the channels **56** may be tapered. For example, as shown in FIG. **9**, the width **90** of each of the channels **56** may be reduced through the length **98** of the channel **56** in the direction of air flow **84** through the channel **56**. Alternately, the width **90** of each of the channels **56** may be enlarged through the length **98** of the channel **56** in the direction of air flow **84** through the channel **56**.

Each of the plurality of channels **56** may also have a depth **94**. In one embodiment, for example, the depth **94** of the channels **56** may be approximately 0.05 inches, 0.10 inches, 0.15 inches, 0.20 inches, 0.25 inches, or 0.30 inches. In other embodiments, the depth **94** of the channels **56** may be less than 0.05 inches or greater than 0.30 inches. Further, in one embodiment, the depth **94** of each of the channels **56** may be substantially constant throughout the length **98** of the channel. However, in another embodiment, the depth **94** of each of the channel **56** may be tapered. For example, the depth **94** of each of the channels **56** may be reduced through the length **98** of the channel **56** in the direction of air flow **84** through the channel **56**. Alternately, the depth **94** of each of the channels **56** may be enlarged through the length **98** of the channel **56** in the direction of air flow **84** through the channel **56**.

The bypass openings **41** may provide an air flow **43** directly into the combustion chamber **38**, thus providing an additional cooling film along the inner surface of the combustor liner **34**, thereby further enhancing cooling of the combustor liner **34**. In one embodiment, for example, the bypass openings **41** may have diameters of approximately 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, or 0.10 inches or, in other embodiments, less than 0.01 inches or greater than 0.10 inches.

Referring now to FIG. **5**, a partial cross-sectional side view of the combustor **14** within the circular region defined by the arcuate line **5-5** in FIG. **2** is shown. Particularly, FIG. **5** shows in more detail the air flow **84** directed from the inlet passages **68** into and through the channels **56** defined on the downstream end portion **52** of the combustor liner **34**, cooling the downstream end portion **52**. As discussed above, air flow **72** discharged by the compressor **12** may be received in the air flow path **47**, defined by the impingement sleeve **42** and the transition piece **46**, through the inlets **48**. In the present embodiment, the inlets **48** are circular-shaped holes, although in other implementations, the inlets **48** may be slots, or a combination of holes and slots of other geometries. As the air flow **72** within the air flow path **47** is channeled upstream relative to the direction of the hot gas path **39**, the majority of the air flow **72** is discharged into the air flow path **36**, defined by the flow sleeve **32** and the combustor liner **34**. As discussed above, the flow sleeve **32** may include the mounting flange **44** at a downstream end **74** configured to receive a member **76** extending radially outward from the upstream end **78** of the impingement sleeve **42**, thereby fluidly coupling the flow sleeve **32** and impingement sleeve **42**. In addition to receiving the air flow **72** from the air flow path **47**, the air flow path **36** may also receive a portion of the air flow **72** from the discharge plenum **31** by way of the inlets **40**. Thus, the air flow **72** within the air flow path **36** may include air flow **72** discharged from the annular passage **47** and air flow **72** flowing through the inlets **40**. Thus, an air flow path that is directed upstream with respect to the hot gas path **39** is defined by the air flow paths **36** and **47**. Additionally, it should be understood that, like the inlets **48** on the impingement sleeve **42**, the inlets **40** may also include holes, slots, or a combination thereof, of various shapes.

While a majority of the air flow **72** flowing through the air flow path **47** is discharged into the air flow path **36**, a portion **84** of the air flow **72** may be provided to the downstream end portion **52** of the combustor liner **34**. For example, as the air flow **72** flows through the combustor **14**, discharge plenum **31**, and air flow paths **36** and **47**, the inlet passages **68** may be configured to accept at least a portion **84** of the air flow **72** from the combustor **14**, discharge plenum **31**, and air flow paths **36** and **47**, as discussed above. The inlet passages **68** may provide this portion of the air flow **84** to the downstream end portion **52** of the combustor liner **34**. As discussed above, the portion **84** of the air flow **72** may be directed from the inlet passages **68** through the channels **56** on the downstream end portion **52** of the combustor liner **34**, cooling the downstream end portion **52**. Though only one channel **56** is shown in the cross-sectional view of FIG. **5**, it should be understood that a similar air flow scheme may be applied to each of the channels **56** on the downstream end portion **52**. In one embodiment, the total air flow **84** directed into and through the channels **56** about the downstream end portion **52** may represent approximately 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 percent of the total air flow **72** supplied to the combustor **14**. In other embodiments, the total air flow **84** directed into the channels **56** may be more than 10 percent or less than 1 percent of the total air flow **72** supplied to the combustor **14**.

As discussed above, the air flow **84** that is provided to the channels **56** may be generally substantially cooler relative to the hot gas flow **73** in the hot gas path **39** within the combustion chamber **38**. Thus, as the air flow **84** flows through the channels **56**, heat may be transferred away from the combustor liner **34**, particularly the downstream end portion **52** of the combustor liner **34**. By way of example, the mechanism employed in cooling the combustor liner **34** may be forced convective heat transfer resulting from the contact between the air flow **84** and the outer surface of downstream end portion **52**, which may include the grooves and dividing members **62** defining the channels **56**, as discussed above. The cooling air **84** may flow in a generally helical direction through the channels **56** along the length of the downstream end portion **52**. Because the air **84** flows in a generally helical direction through the channels **56**, and because the length of the channels **56** is generally longer than the axial length L**2** of the downstream end portion **52**, the residence time of the air flow **84** within the channels **56** is increased, resulting in increased cooling of the downstream end portion **52**. The air flow **84** may then exit the channels **56**, thereby discharging into the transition piece cavity **50**. The air flow **84** may then be directed towards and mix with the hot gas flow **73** flowing downstream through hot gas path **39** from combustion chamber **38** through transition piece cavity **50**.

Additionally, FIG. **5** illustrates the use of multiple sets of bypass openings **41**. For instance, referring back to the embodiment shown in FIGS. **3** and **4**, a single set of bypass openings **41** disposed circumferentially about the combustor liner **34** is illustrated. As shown in FIG. **5**, three such sets of axially spaced bypass openings **41** may be utilized in cooling the combustor liner **34**. That is, each of the bypass openings shown in the cross-sectional view of FIG. **5** may correspond to a respective set of bypass openings arranged circumferentially about the combustor liner **34**. A portion **43** of the air flow **72** from the air flow path **36** may flow through each of the bypass openings **41** into the combustion chamber **38**. As discussed above, this air flow **43** may provide a cooling film, thus further improving the insulation of the combustor liner **34** from the hot gas flow **73** within the combustion chamber **38**. It should be understood that the sets of bypass openings **41** are not limited to one set or three sets, but may be two sets, four sets, or any other number or variety of sets.

As shown in FIG. **6**, in one embodiment, each of the plurality of channels **56** of the present disclosure may have a substantially smooth surface, such as a substantially smooth channel surface **95** and sidewalls **92**. For example, the channel surface **95** and sidewalls **92** of each of the channels **56** may be substantially or entirely free of protrusions, recesses, or surface texture. As air flow **84** flows through the channels **56** in the generally downstream direction and contacts the channel surface **95** and sidewalls **92** of each channel **56**, heat may be transferred away from the combustor liner **34**, particularly the downstream end portion **52** of the combustor liner **34**, via forced convection cooling.

As shown in FIG. **7**, in an alternative embodiment, each of the plurality of channels **56** of the present disclosure may have a surface, such as channel surface **95** and sidewalls **92**, that includes a plurality of surface features **96**. The surface features **96** may be discrete protrusions extending from the channel surface **95** or sidewalls **92**. For example, the surface features may include fin-shaped protrusions, cylindrical-shaped protrusions, ring-shaped protrusions, chevron-shaped protrusions, raised portions between cross-hatched grooves formed within the channel **56**, or some combination thereof, as well as any other suitable geometric shape. It should be appreciated that the dimensions of the surface features **96** may be selected to optimize cooling while satisfying the geometric constraints of the channels **56**. The surface features **96** may further enhance the forced convective cooling of the combustor liner **34** by increasing the surface area of the downstream end portion **52** which the cooling air flow **84** may contact as it flows through the channel **56**. Thus, as the air flow **84** flows through the channels **56** and contacts the surface features **96**, the amount of heat transferred away from the combustor liner **34** may be greater relative to the embodiment shown in FIG. **6**. Further, while the presently illustrated embodiments show surface features **96** formed only on the channel surface **95**, in other embodiments, the surface features **96** may be formed only on the sidewalls **92** of the channel **56**, or on both the surface **95** and sidewalls **92** of the channel **56**.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A combustor liner comprising:

an upstream portion having a radius and a length along a generally longitudinal axis, the upstream portion defining a plurality of bypass holes; and

a downstream end portion having a radius and a length along the generally longitudinal axis, the downstream portion extending downstream from the plurality of bypass holes in an air flow direction, an outer surface of the downstream end portion defining a plurality of channels, each of the plurality of channels defined only in the downstream end portion and extending helically through the length of the downstream end portion,

wherein each of the plurality of channels is configured to flow an air flow therethrough, cooling the downstream end portion,

and wherein the radius of at least a portion of the downstream end portion is less than the radius of the upstream portion.

2. The combustor liner of claim **1**, wherein each of the plurality of channels extends helically through approximately the entire length of the downstream end portion.

3. The combustor liner of claim **1**, wherein each of the plurality of channels extends helically through only a portion of the length of the downstream end portion.

4. The combustor liner of claim **1**, wherein each of the plurality of channels has a length greater than the length of the downstream end portion.

5. The combustor liner of claim **1**, wherein each of the plurality of channels has a width, and wherein the width of each of the plurality of channels is substantially constant throughout the length of the channel.

6. The combustor liner of claim **5**, wherein the width of each of the channels is in the range from approximately 0.25 inches to approximately 1 inch.

7. The combustor liner of claim **1**, wherein each of the plurality of channels has a width, and wherein the width of each of the plurality of channels is reduced through the length of the channel in the direction of the air flow through the channel.

8. The combustor liner of claim **1**, wherein each of the plurality of channels has a substantially smooth surface.

9. The combustor liner of claim **1**, wherein each of the plurality of channels has a surface that includes a plurality of surface features.

10. The combustor liner of claim **1**, wherein each of the plurality of channels has a depth, and wherein the depth of each of the plurality of channels is substantially constant throughout the length of the channel.

11. The combustor liner of claim **10**, wherein the depth is in the range from approximately 0.05 inches to approximately 0.3 inches.

12. The combustor liner of claim **1**, wherein each of the plurality of channels has a depth, and wherein the depth of each of the plurality of channels is reduced through the length of the channel in the direction of the air flow through the channel.

13. The combustor liner of claim **1**, wherein the length of each of the plurality of channels is in the range from approximately 4 inches to approximately 16 inches.

14. The combustor liner of claim **1**, wherein the length of the downstream end portion is in the range from approximately 3 inches to approximately 12 inches.

15. The combustor liner of claim **1**, wherein the length of the downstream end portion is less than the length of the upstream portion.

16. The combustor liner of claim **1**, wherein the radius of the downstream end portion is generally less than the radius of the upstream portion.

17. The combustor liner of claim **1**, wherein the radius of the downstream end portion is reduced throughout the length of the downstream end portion in the direction of the air flow through the plurality of channels.

18. The combustor liner of claim **1**, wherein the radius of the upstream portion is reduced throughout a portion of the length of the upstream portion in the direction of the air flow through the plurality of channels.

19. A combustor comprising:

a combustor liner at least partially defining a hot gas path, the combustor liner including an upstream portion and a downstream end portion, the upstream portion defining a plurality of bypass holes, the upstream portion and the downstream end portion each having a radius and a length along a generally longitudinal axis, the downstream portion extending downstream from the plurality of bypass holes in an air flow direction, and wherein the radius of at least a portion of the downstream end portion is less than the radius of the upstream portion;

a transition piece coupled to the combustor liner and further defining the hot gas path; and

an annular wrapper disposed between the combustor liner and the transition piece, the annular wrapper defining a plurality of inlet passages, the plurality of inlet passages configured to provide an air flow to the downstream end portion of the combustor liner,

wherein an outer surface of the downstream end portion of the combustor liner defines a plurality of channels, each of the plurality of channels defined only in the downstream end portion and extending helically through the length of the downstream end portion, and wherein the air flow is directed from the inlet passages through the plurality of channels, cooling the downstream end portion.

20. The combustor of claim **19**, wherein each of the plurality of channels has a length greater than the length of the downstream end portion.

* * * * *